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6. AUTHOR(S)

Dr. Matthew Welborn (technical)
Ms. Samantha Venters (cost summary)

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5e. TASK NUMBER

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Signal Innovations Group, Inc.
1009 Slater Rd., Ste. 200
Durham, NC 27703

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Over the course of the past two months, significant progress has been made towards adding the final features necessary for the video tracking system. The code has successfully transitioned into its final format in C for efficient implementation, allow us to perform significant optimizations and achieve very efficient running times, on the order of 35 fps. We have also added important capabilities for object tracking across multiple cameras, object classification (allowing behavior analysis to be conditioned on the type of object observed), and virtual pan/tilt/zoom capabilities.

15. SUBJECT TERMS

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1. REPORT DATE. Full publication date, including day, month, if available. Must cite at least the year and be Year 2000 compliant, e.g. 30-06-1998; xx-06-1998; xx-xx-1998.

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1 Summary

The purpose of this program is to address the development of algorithms for adaptive processing of multi-sensor data, employing feedback to optimize the linkage between observed data and sensor control. The envisioned multi-modal adaptive system is applicable for intelligence, surveillance, and reconnaissance (ISR) in general environments, addressing base and port security, as well as urban and suburban sensing during wartime and peace-keeping operations. Of significant importance for current and anticipated DoD activities, the ISR system is designed to detect asymmetric threats, with the goal of recognizing unusual behavior or activities. Technologies and systems developed under this effort will be designed for semi-automated scene awareness, with the objective of recognizing behavior that appears atypical (e.g. atypical object motion, and dynamic characteristics of people and vehicles). Leveraging our previously developed technology, SIG is developing second-generation methods to adaptively learn the statistics of dynamic object behavior in video, while focusing on defining system requirements for sensor deployment by using field data (vs. highly controlled indoor data). SIG is also working closely with its subcontractor, Lockheed Martin, to integrate additional technologies, such as object classification and recognition, to provide a more robust and discriminative system. Additionally, SIG is cooperating with the Navy's China Lake facility to collect representative data for a deployed system, and to specify requirements and features necessary of such a system. Finally, SIG is coordinating with Integrian on prototype development schedules and product integration requirements, and defining a joint marketing and commercialization strategy for such products.

2 Technical Developments

Over the course of the past two months, significant progress has been made towards adding the final features necessary for the video tracking system. The code has successfully transitioned into its final format in C for efficient implementation, allow us to perform significant optimizations and achieve very efficient running times, on the order of 35 fps. We have also added important capabilities for object tracking across multiple cameras, object classification (allowing behavior analysis to be conditioned on the type of object observed), and virtual pan/tilt/zoom capabilities.

2.1 C code and Optimizations

Finishing the work started last reporting period, SIG has completed the transition of the code from the research rapid development environment in Matlab into the more efficient and flexible C code, which will be the format for the final delivered code. The final development in C code allows significant benefits for the system, including efficiency, flexibility, and portability. It also allows direct access to a variety of different types of camera video streams, capable of utilizing the camera developer's own highly efficient camera interface libraries for data input and camera control.

One of the primary benefits of a C implementation is the increased memory and processing efficiency possible in a lower level compiled system. Significant time has been spent optimizing the tracking code, and we have achieved highly successful results. Intentionally testing on an older, lowered powered system, we used a 1.7 GHz Pentium M processor, which is more indicative of the anticipated system that would be readily available for a complete anomalous behavior detection system. On our benchmark testing sequences, including up to four objects moving simultaneously on screen, we are able to achieve speeds of 35 frames per second, well in excess of our targeted 15 fps. This provides plenty of leeway for inclusion of additional processing to handle the more advanced features we anticipate including over the next couple of months.

2.2 Multi-camera Tracking

To maximally leverage the power of a multi-camera system, it is critical to be able to track objects as they pass from the field of view of one camera to another. While tracking each object separately for each camera may be possible, the data association problem can be difficult, as many viewing conditions can differ between the two cameras, such as viewing angle, distance, lighting conditions, and occlusions.

Our proposed solution specifically seeks to create observation models which take these viewing conditions into account to create a probabilistic set of associations. Specifically, we consider the *joint* probability of association, which allows all of the observable data to be treated in a relative fashion. Given that an observed pair of people in one camera could be associated with two other people in a second camera, it can be challenging to accurately model the probability of association for each one independently. However, when considering the joint probability, the factors which are most relevant become the relative differences. For instance, different viewing angles can make modeling the expected position for an object in the second camera very difficult, the joint probability is able to normalize out much of this noise, and instead focus on preserving the relative positions of the different objects.

Initial work has already been completed to implement this approach, and has been tested on our data. The results have been very encouraging, and as this technology matures, it will be integrated with the behavior modeling and analysis component of the system. This will provide significantly greater amounts of information for the system to work with, and be able to analyze potentially suspicious behavior across a significantly broader period of time, providing a corresponding increase in the discriminative power of the system.

2.3 Object Classification

In the recent reporting period, we have implemented algorithms to perform classification of tracked foreground objects into one of multiple predefined object classes. This classification mechanism is based on shape characteristics as captured by the probabilistic shape models maintained internal to the Bayesian tracking engine. To reduce the complexity of the classification, we distill the shape model into a number of easily computed characteristics, such as height and width. The classification determined from each of these individual characteristics can be combined in a principled manner to achieve accurate distributions. This concept has been applied to classification in many different ways before, such Ada-boost or bootstrapping methods. We have taken these ideas, and updated them to be included in our Bayesian framework. This provides a principled way of conditioning the expected behavior of the objects on their appearance.

$$p(pose \mid models, shape) = \Sigma_{class}\, p(pose \mid class, models)\, p(class \mid shape)$$

The initial classifier performance is encouraging and further refinements are being made based on additional data sets. The classifier is able to make decisions not just about individual shape classes (e.g. pedestrian versus vehicle), but also identifying other features such as presence of multiple pedestrians in a group that might otherwise be difficult to discern based on simple features such as velocity or position alone.

2.4 Virtual Pan/Tilt/Zoom

One of the objectives of the current project work is to use the information extracted from the video detection and tracking engine to perform not only behavior analysis, but to also perform active sensor management that can enhance the information gained from objects identified by the tracking system. Camera technology trends and our own analysis results indicate that a promising approach to implement a Sensor Management Agent (SMA) would be to use it to create a 'virtual' zoom and pan functions that will be used in conjunction with high resolution digital video cameras to achieve the same effect with much better control and flexibility.

For typical video scenes, video analytic processing and accurate object tracking can be performed at lower resolution without loss in robustness but with a savings in computational load as well as internal data communications bandwidth. When objects of interest are detected in the video scene, it is often useful to create a 'virtual zoom' camera by processing the area of interest at higher resolution beyond the level that is needed to simply maintain tracking of the object. As the object moves, the system can track its motion and ensure that the high resolution 'virtual zoom' area is panned with the moving object of interest to support extraction of object features and/or display at higher resolution.

We have created the basic framework necessary for this approach of SMA in our current implementation. The method is based on identifying regions of interest, as specified by the tracking algorithm. Since moving objects are the pertinent portions of the image, it is intuitive that it is these sections which are most informative to concentrate, or "zoom" in on. The tracking algorithm provides both a predictive and a posterior estimation of the objects, allowing for a consistent "pan/tilt" mechanism, to provide continuity for a single virtual zoom. These areas can then be extracted and sent along either for more processing, or along a narrow bandwidth connection for visualization purposes. This framework provides visualizations that demonstrate a virtual pan/zoom function based on tracked objects as well as necessary features to support acoustic fusion as discussed below.

3 Acoustic Array

In addition to efficient extraction of visual information, this same virtual pan/zoom framework will be useful as we extend the same concept to additional types of sensors or processing regimes that are controlled by the low level object detection and tracking engine to extract even more information about the objects of interest that are being examined in the process of asymmetric threat detection.

In addition to our video work, SIG has moved forward with the internal development project (not developed on SEALS funding) to build a linear acoustic array that can collect acoustic data synchronized with color video data to create a real-time acoustic beam that can listen to a stationary or moving object under the control of the video tracking system. SIG has completed initial analysis of this acoustic array sensor and we are proceeding with data collection efforts as we work to fuse this sensor data with the ongoing video tracking effort. Figure 2 shows results of modeling this sensor to determine potential acoustic gain available to extract acoustic information in a multi-sensor tracking application.

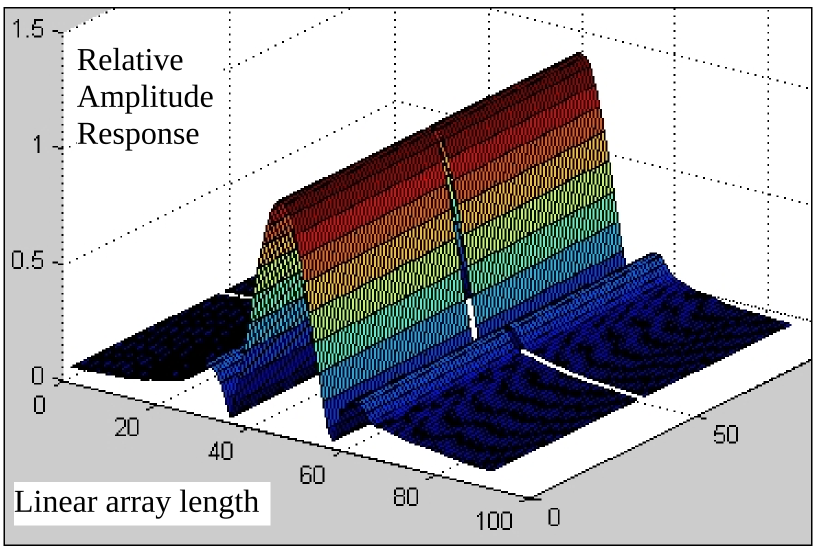

Figure 2: Initial results for antenna array gain pattern modeling showing that significant azimuth gain can be achieved with a linear array, as well as potential ability to null nearby acoustics sources.

4 Future Directions

During the next reporting period, our goal is to finish integrating more advanced methods into the tracking system to allow us to achieve the highest levels of discrimination in the most challenging situations of the our data collections. We will focus specifically on apparent object separation and merging instances, for example, when a person exits or enters a vehicle, or when they drop off or pick up a package. Another area of improvement will consider the challenges that can arise when objects remain on screen for an extended period of time, or loiter in place for a long time. This situation has particularly strong implications for the color models used, which are currently being examined. The more recent features of the tracking algorithm, such as object classification and trans-camera tracking, will be tightly integrated into the behavior analysis section of the system, to provide more discriminative and informative results.

In addition to this near-term work, we are continuing to plan our efforts for the Year III research that ONR has indicated will be funded. One key aspect of this next year, as indicated previously, is to work toward transitioning the research to other efforts, such as the DARPA LACOSTE. In this effort and others, an important component of the sensor framework involves compressive-sensing and other related concepts to address the very high envisioned data rates. This compressive-sensing construct involves non-adaptive random sampling, while related constructs such as value-of-information sensor management algorithms are adaptive and non-random. Given ONR's interest in compressive sensing, within the final year of this program these two approaches will be investigated in the context of high-bit-rate video collections.

		Signal Inovations Group, Inc. Quarterly Cost Report Option 1 (08/28/2007 - 11/27/2007) N00014-05-C-0294 *CONTINUATION SHEET*				SCHEDULE NO. SHEET NO.
U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT OFFICE OF NAVAL RESEARCH						
NUMBER AND DATE OF ORDER	DATE OF DELIVERY OR SERVICE	ARTICLES OR SERVICES *(Enter description, item number of contract or Federal supply schedule, and other information deemed necessary)*	QUAN-TITY	UNIT PRICE COST	PER	AMOUNT
		N00014-05-C-0294				
		Signal Innovations Group, Inc. 1009 Slater Rd., Ste. 200 Durham, NC 27703				
		CONTRACT VALUE:				
		Estimated Cost				$ 723,483
		Fixed Fee				57,878
		Total Estimated Cost Plus Fixed Fee				$ 781,361
		FUNDED AMOUNT:				
		Estimated Cost				$ 368,541
		Fixed Fee				29,483
		Total Estimated Cost Plus Fixed Fee				$ 398,024
		Major Cost Elements:		CURRENT		CUMULATIVE
		Direct Labor		7,362.73		88,578.20
		Benefits		2,200.86		24,497.92
		Subtotal		9,563.59		113,076.12
		Expenses:				
		Travel		0.00		3,017.00
		Subcontract Expense		111,265.00		174,189.00
		Other Direct Costs		0.00		316.41
		Expenses Subtotal		111,265.00		177,522.41
		Overhead		5,247.43		60,545.38
		Subtotal		126,076.02		351,143.91
		Fee 8%		8,148.17		26,153.64
		Total Amount Due SIG		134,224.19		377,297.54